W. D. Surface

The effect of music on
the metabolic rate of
workers

THESIS
S 864

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA 93943-5002

THE EFFECT OF MUSIC
ON THE
METABOLIC RATE
OF
WORKERS

A Thesis
Submitted to the Faculty
of
Purdue University
by
Wayne Douglas Surface
In Partial Fulfillment of the
Requirements for the Degree
of
Master of Science
June, 1951

Thesis
S864

ACKNOWLEDGMENTS

Sincere acknowledgment is made to Ass't. Professor Wallace J. Richardson, my major professor, for his valuable guidance and assistance. Acknowledgment is also made to my wife who was of great help in the preparation of the manuscript.

15651

TABLE OF CONTENTS

Page

ABSTRACT . . . .

INTRODUCTION 1

EXPERIMENTAL PROCEDURE 4

Purpose 4

Method 4

Task 6

Test Procedure 7

CALCULATIONS, RESULTS AND CONCLUSIONS 10

Calculations 10

Results 12

Conclusions 12

APPENDIX A. TABLES 14

APPENDIX B. COMPUTATIONS 19

APPENDIX C. SAMPLE CHART 32

APPENDIX D. PHOTOGRAPHS OF WORKPLACE AND TASK . . . 34

BIBLIOGRAPHY 36

LIST OF TABLES AND COMPUTATIONS

List of Tables Page

1. Characteristics of Individuals Tested 15
2. Order of Presentation of Noise and Music . . . 16
3. Calculated Slopes of Lines of Best Fit, By Musical Selection 17
4. Calculated Slopes of Lines of Best Fit, By Order of Presentation 18

List of Computations Page

1. L_1 Test for Homogeneity of Variances 20
2. Analysis of Variance 30

ABSTRACT

Prior to 1940 there were few industrial plants in which the workers could listen to music while they worked. The situation is now such that almost the reverse is true. The tremendous increase in the playing of music in industry has caused, and in turn has been caused by, many studies of the effects of music in terms of higher production rates, better employee morale and the resultant better employee-employer relations.

While the factor of a change in the motivation of the employees has most likely been responsible for some of the cases in which an increase in the rate of production has been observed, it seemed possible that some physiological change might have been produced in the employees by the music, which change could account for some of the increase in the production rates. If the physiological change were such as to cause a reduction in the energy expenditure necessary to perform any given task, then that task could be performed a greater number of times for the same total energy expenditure as was used before the change took place.

A method for the quantitative determination of human energy expenditure does exist. This method consists of the measurement of the body metabolism.

Previous work at Purdue University has demonstrated that a medical metabolism tester is capable of detecting small

changes in human energy expenditure.[1] The tester used in this previous work was a standard model manufactured by the Sanborn Company. This same tester was used in this experiment for the determination of the energy expenditure requirements attributable to the effect of music.

The body metabolism rates of ten persons were measured while these persons were subjected to backgrounds of noise and to backgrounds of noise plus music. While subjected to these backgrounds, all persons performed the same task, at the same fixed pace, for the same lengths of time. Environmental conditions and all other factors associated with the conduct of the experiment were held as nearly constant as possible. Five metabolism rates were obtained for each person. The first and fifth rates were taken when only the noise background was being used. Each of the other three rates was taken with a background of noise plus music. The noise was produced by a recording of an operating automatic screw machine and it was kept at a constant level of eighty decibels. Three different musical recordings were used and the average noise level of each was also kept constant at eighty decibels.

A statistical analysis of the metabolic rates thus obtained indicates that there is no significant variation be-

---

[1] Tilles, S., An Investigation of The Suitability of The Sanborn EIS Metabolism Tester To Basic Motion Study Experimentation, Master of Science Thesis, Purdue University, Lafayette, Indiana, 1949.

tween the rates for the three musical selections nor is there a significant variation between the rates for the conditions of noise versus noise plus music. Any physiological change which may have been produced by the music is not evidenced by a corresponding change in the body metabolism.

THE EFFECT OF MUSIC ON THE METABOLIC RATE OF WORKERS

INTRODUCTION

The problem of accounting for the higher rates of production which have accompanied the introduction of periods of musical programming in some industrial installations is an interesting one. While the investigation of the effect of certain types of music on the metabolic rates of workers was the announced purpose of this thesis, another purpose, and perhaps the most important one, was the investigation of the feasibility of the use of the Sanborn EIS metabolism tester to evaluate the effects of other mental and emotional stimuli upon the individual in an industrial situation. Any method of measuring the effects of such stimuli would be a valuable industrial engineering tool.

A survey of the literature discloses that music tends to affect the psychogalvanic reflex, electrocardiogram, blood pressure, pulse, and breathing rate.[2]

By auditory stimuli, metabolism can be controlled, muscular fatigue can be increased or decreased, and the threshold of sensory perception can be controlled.[3] It has been shown that traffic and office noises initially affect the metabolic rates of persons doing clerical tasks, but that after a period of adjustment to the noises, the length of

---

2. Pepinsky, A., "The Growing Appreciation of Music and Its Effect Upon the Choice of Music in Industry," Journal of the Acoustical Society of America, January,1944,vol.15,pp.176-9.

3. Burris-Meyer, H., "Music In Industry; Results of Test," Mechanical Engineering, January 1943, vol. 65, pp. 31-4.

which period varies with the person being tested, the metabolic rates return to their pre-noise values.[4]

There are widespread misconceptions of the effect of music in industry. Some of these are as follows:[5]

> Music (any music) plus industry (any industry) equals music in industry. Music thus defined is a good thing. It works like a slot machine; you put in the music and out comes your production increase.
>
> Feed people the auditory equivalent of candy and they will be grateful to you.
>
> Base programming on a music popularity poll. Give them what they ask for; after all, the purpose is to keep them happy.

The primary objective of music in industry must be the establishment and maintenance of a desired emotional relationship between the man, his work and his environment.

It must turn the employee out at the end of the day in a better psychological and physiological condition than he would have enjoyed had no music been employed.[6] The same can be said of any mental or emotional stimulus to which the employee might be exposed. Obviously, some method of measur-

---

[4] Harmon, F.L., "The Effects of Noise Upon Certain Psychological And Physiological Processes," Archives of Psychology, February, 1933, No. 147.

[5] Cardinell, R.L. and Burris-Meyer, H., "Music In Industry Today," Journal Of The Acoustical Society Of America, July, 1947, vol. 19, no. 4, pt. 1, pp. 547-9.

[6] Ibid.

ing the effects of various stimuli is needed. It was thought that the Sanborn EIS metabolic tester might be the tool around which such a method could be built.

EXPERIMENTAL PROCEDURE

Purpose

The primary purpose of this experiment was to determine the effect, if any, of music upon the rate of energy expenditure of workers performing a prescribed task. If a relationship were shown to exist between the presence or absence of music and the rate of energy expenditure, a secondary purpose was to be the determination of the type of music which produces the smallest rate of energy expenditure.

Method

It was decided that the Sanborn EIS metabolism tester would be used to measure the rates of energy expenditure by measuring the metabolic rates of the workers while they were performing the prescribed task with a background of random noise and with a background of random noise plus selected types of music.

In order to minimize the effects of variables other than the music; the prescribed task, the pace, the noise level (both background and music), and the testing schedule were fixed for all workers and for all tests given to each worker. The order in which the types of music were presented to each worker was randomized so as to eliminate any trends attributable to the order of presentation. Table 2 shows the order of presentation used for each worker.

The types of music used were selected from among the thirteen types on which attitude measurements, as shown on

the "Attitudes Towards Music" scale developed by RCA, were available.[7] The selections were:

Washington Post, March, American Legion Band of Hollywood, California, Joe Colling, Director. Decca Personality Series, 23921 A.

Copenhagen, Instrumental, Pee Wee Hunt And His Orchestra. Capitol, 1319.

Blue Danube, Waltz, Wayne King and His Orchestra. RCA Victor, 27516 A.

The task was a simple one, repetitive in nature, so as to remove the effects of practice from the physical and mental ease with which the task might be performed.

The use of a controlled and fixed pace for the performance of the task was made necessary by the fact that pace has been shown to affect the metabolic rate.[8]

A background of random noise was used for two reasons. First, the random noise level could be controlled at a fixed value (80 decibels) for all tasks, and second, the random noise background would more nearly approximate the background noise to be found in an actual industrial situation.

The noise level of the music played was kept constant (80 decibels) since variations in noise level produce attitudes of annoyance in some people[9] and this annoyance could

---

[7] Kerr, W.A., "Attitudes Towards Types Of Industrial Music," Journal Of The Acoustical Society Of America, October, 1943, vol. 15, pp. 125-30.

[8] Hoover, J.E., Analysis Of Variation Of Human Energy Consumption With Length Of Movement Under Equal Pace, Master Of Science Thesis, Purdue University, Lafayette, Indiana, August, 1950.

[9] Halpin, D.D., "Industrial Music And Morale," Journal Of The Acoustical Society Of America, October, 1943, vol.15, pp.116-23.

be reflected in test results.

Task

The task performed by the workers consisted of taking polished steel balls, one at a time, from the end of a rubber tube and transporting the balls to the other end of the tube into which they were dropped. The balls weighed approximately three-fourths of an ounce each and were eleven-sixteenths of an inch in diameter. The rubber tube was of three-fourths inch inside diameter, eighteen inches long, and was mounted in such a way that one end was eight inches above and fourteen inches to one side of the other end. The upper end was forced over a one inch outside diameter, three-fourths inch inside diameter, two inch long piece of pipe which in turn was inserted in a hole in a wooden platform. The hole in the platform was countersunk so as to provide a slight funneling effect. The lower end of the tube was cut away so as to provide an open trough for the last inch of the ball's travel. A stop was provided against which the balls came to rest. The workers moved the balls from the lower end of the tube to the upper end, using one arm only, at the rate of forty-eight balls per minute. This pace was controlled and facilitated by having the workers coordinate their arm movements with the pendulum of a metronome which was set to make ninety-eight beats per minute. The workers were coached to disregard any dropped balls and to continue the arm movement without a ball rather than to break the established rhythm in an effort to retrieve

a ball or pick up another one. Dropped balls were fed back into the tube by the person conducting the experiment. Before the experiment began, each worker was seated in a chair before the workplace in whichever position best suited him. This position was held throughout the experiment.

Test Procedure

The test was conducted in a room from which all persons were excluded with the exception of the worker and the person conducting the experiment. In this manner, many distracting influences, which might have affected the test results, were eliminated. On a day prior to the day of the test, each worker was given a briefing on the purpose of the test, the nature of the metabolic equipment, and the manner in which the task was to be performed. Each worker then practiced the task for ten minutes during which time he was exposed to periods of noise and noise plus music. During this time the worker was connected to the metabolic tester in order to accustom him to its use. No mention of the expected results or previous results was made to the worker at any time.

All tests on all workers followed the same schedule. With the time of arrival of the worker at the testing room as "zero" time, the following schedule was adhered to at all times:

Time	Elapsed Time	Action
0-10	10 minutes	A recording of noise was started and brought to a level of eighty

		decibels. The worker rested on a cot. Just prior to the end of the ten minute period, the worker was seated in the chair at the work area and was connected to the metabolic tester.
10-15	5 minutes	The worker performed the task while breathing room air through the metabolic equipment.
15-20	5 minutes	Without knowledge of the worker the metabolic equipment was turned on and a record run was made.
20-25	5 minutes	The worker was disconnected from the equipment but remained seated at the work area.
25-30	5 minutes	A recording of music was started. The worker was connected to the equipment and performed the task while breathing room air through the equipment.
30-35	5 minutes	Without knowledge of the worker, the metabolic equipment was turned on and a record run was made, after which the music was stopped.
35-40	5 minutes	Same as 20-25
40-45	5 minutes	Same as 25-30
45-50	5 minutes	Same as 30-35
50-55	5 minutes	Same as 20-25
55-60	5 minutes	Same as 25-30

60-65	5 minutes	Same as 30-35
65-70	5 minutes	Same as 20-25
70-75	5 minutes	Same as 10-15
75-80	5 minutes	Same as 15-20

CALCULATIONS, RESULTS AND CONCLUSIONS

Calculations

The Sanborn EIS metabolic tester is designed to measure the metabolic rate by measuring the rate of oxygen consumption. Essentially, the tester consists of a set of breathing tubes which lead to a spirometer bell which is free to rise and fall in an enclosing water tank as the volume of gases in the bell increases or decreases. The bell is filled with oxygen before the start of each test. As the individual being tested inhales through the breathing tubes, he draws oxygen from the spirometer bell, and the bell falls. As the individual exhales, the products of exhalation pass to the bell via a filter which removes the carbon dioxide that has been generated by the individual's energy expenditure. Thus, the bell, while rising, does not rise to its original position. The difference in height between the positions of the bell after successive exhalations is a measure of the amount of oxygen consumed by the individual between these exhalations.

Through a system of linkages, a stylus is attached to the bell and moves with it. This stylus traces the vertical movements of the bell on a paper-backed, wax-faced chart wrapped around a cylinder. The cylinder is turned by a synchronous motor. Therefore, the ordinates of the saw-toothed line inscribed on the chart represent the vertical positions of the spirometer bell and the abscissa of the chart represent time.

If the person being tested consumes oxygen at a constant

rate, and the tidal volume (i.e., volume retained in the lungs at the end of each inhalation and exhalation) remains constant, as would occur when a perfect operator performed a repetitive task at a constant pace, the peaks of the saw toothed graph generated by the metabolic equipment form a straight line.[10] The slope of this line represents the rate of oxygen consumption or energy expenditure.

Since the individuals tested were not perfect operators, the volumes of the respiratory cycles were not constant, and the peaks of the charts did not fall on a straight line. It was necessary to calculate the slope of the line of best fit through the points of each chart using the method of least squares. Since each chart represented all the respiratory cycles for a four minute period (45-90 cycles), a sampling plan was devised which allowed the computation of the slope of the line of best fit from as few as thirty peak points. These points were selected as follows: five from the first ten points of the chart; five from the last ten points of the chart; and at least twenty equally spaced throughout the remaining points of the chart. The results of the calculations are given in Table 3 and Table 4.

The L_1 test for homogeneity of variance[11] was applied to the data. The analysis of variance technique[12] was then used

---

10. Zeothout, W.D., A Textbook Of Physiology; St.Louis, C.V. Mosby Co., 1938.

11. Freeman, H.A., Industrial Statistics; New York, J.Wiley and Sons, Inc., London, Chapman and Hall, Ltd., 1942.

12. Lindquist, E.F., Statistical Analysis In Educational Research, Boston, New York, Chicago, Atlanta, Dallas, San Francisco, Houghton Mifflin Company, 1940.

to evaluate the significance of the data.

All the raw data for the calculations are deposited in the Motion and Time Laboratory at Purdue University.

Results

The L_1 test for homogeneity of variances upheld the hypothesis that the column samples belonged to normal populations of the same variance. The test rejected the hypothesis that the r~~a~~ow samples belonged to normal populations of the same variance.

The analysis of variance indicated that the only significant variance at either the 5% or 1% level was the variance between individuals. There was no significant variance attributable to the presence or absence of music, nor was there a significant variance caused by any specific selection of music. Neither was there a significant variance due to the order of presentation of the musical selections or to the skill which was gained in performing the task between the first and last tests for each individual. The calculations of the L_1 test and the analysis of variance tests are included in Appendix B.

Conclusions

It may be concluded from the results of the experiment that music of the three comprehensive types used does not affect the metabolic rates of workers performing a given task, the energy expenditure requirements of which are a function

of the pace[13] at which the task is performed.

Although statistical studies have shown that factory production has increased when music was used in certain selected industries;[14] the results of this experiment indicate that these production increases probably were not achieved without a corresponding increase in the amount of energy expenditure on the part of the employees.

---

13. Hoover, J.E., Analysis Of Variation Of Human Energy Consumption With Length Of Movement Under Equal Pace, Master of Science Thesis, Purdue University, Lafayette, Indiana, August, 1950.

14. Kerr, W.A., "Experiments On The Effects Of Music On Factory Production," Applied Psychology Monographs, January, 1945, No.5.

of the pace[13] at which the task is performed.

Although statistical studies have shown that factory production has increased when music was used in certain selected industries,[14] the results of this experiment indicate that these production increases probably were not achieved without a corresponding increase in the amount of energy expenditure on the part of the employees.

---

[13] Reeves, J.A., Analysis Of Variation Of [illegible] Energy Expenditure With Level Of [illegible] Under Stress, 1950, Master of Science Thesis, Purdue University, Lafayette, Indiana, August, 1950.

[14] Kerr, W.A., "Experiments On The Effects Of Music On Factory Production," Applied Psychology Monographs, January, 1943, No.5.

APPENDIX

A

TABLE 1

CHARACTERISTICS OF INDIVIDUALS TESTED

Individual	Age	Sex	Race	Height	Weight	Previous Experience With Metabolic Equipment
A	23	M	W	5' 10"	198	None
B	23	M	W	6' 3"	228	None
C	23	M	W	5' 10"	150	None
D	28	M	W	5' 8"	145	None
E	21	M	W	6' 1"	180	Has had basal taken
F	23	M	W	6' 2"	172	None
G	22	M	W	5' 11"	175	None
H	27	F	W	5' 7"	140	None*
I	30	F	W	5' 7"	150	Has had several basals taken
J	29	M	W	5' 11"	165	None

* Accustomed to breathing through mouth during sleep.

TABLE 2

ORDER OF PRESENTATION OF NOISE AND MUSIC

Selection Individual	First	Second	Third	Fourth	Fifth
A	1	2	4	3	1
B	1	3	2	4	1
C	1	4	2	3	1
D	1	2	3	4	1
E	1	3	4	2	1
F	1	4	3	2	1
G	1	2	4	3	1
H	1	3	2	4	1
I	1	2	3	4	1
J	1	3	4	2	1

1	Noise
2	Washington Post March plus Noise
3	Copenhagen plus Noise
4	Blue Danube plus Noise

TABLE 3

CALCULATED SLOPES OF LINES OF BEST FIT
BY MUSICAL SELECTION

Selection Individual	1 (beginning)	2	3	4	1 (ending)
A	.518	.590	.497	.501	.551
B	.691	.718	.724	.713	.690
C	.432	.421	.424	.418	.402
D	.396	.387	.404	.399	.385
E	.457	.512	.464	.509	.445
F	.577	.412	.505	.432	.452
G	.470	.451	.426	.450	.420
H	.327	.316	.337	.329	.331
I	.428	.398	.353	.369	.370
J	.373	.395	.370	.340	.378

1 Noise
2 Washington Post March plus Noise
3 Copenhagen plus Noise
4 Blue Danube plus Noise

(All slopes negative)

TABLE 4

CALCULATED SLOPES OF LINES OF BEST FIT

BY ORDER OF PRESENTATION

Selection Individual	First	Second	Third	Fourth	Fifth
A	.518	.590	.501	.497	.551
B	.691	.724	.718	.713	.690
C	.432	.418	.421	.424	.402
D	.396	.387	.404	.399	.385
E	.457	.464	.509	.512	.445
F	.577	.432	.505	.412	.452
G	.470	.451	.450	.426	.420
H	.327	.337	.316	.329	.331
I	.428	.398	.353	.369	.370
J	.373	.370	.340	.395	.378

(All slopes negative)

APPENDIX

B

L_1 TEST OF COLUMNS OF TABLE 3

(Variance)

Column	SX	SX^2
1 (beginning)	4.669	2.281165
2	4.600	2.240208
3	4.504	2.141052
4	4.460	2.101502
1 (ending)	4.424	2.057604

$$\text{Variance} = \frac{NSX^2 - (SX)^2}{N^2}$$ where N = no. of values per column.

$$\text{Variance}_1 \text{ (beg.)} = \frac{10(2.281165)-(4.669)^2}{10^2} =$$

$$= \frac{22.81165 - 21.79956}{100} = .0101209$$

$$\text{Variance}_2 = \frac{10(2.240208) - (4.600)^2}{10^2}$$

$$= \frac{22.40208 - 21.16000}{100} = .0124208$$

$$\text{Variance}_3 = \frac{10(2.141052) - (4.504)^2}{10^2}$$

$$= \frac{21.41052 - 20.28602}{100} = .011245$$

$$\text{Variance}_4 = \frac{10(2.101502) - (4.460)^2}{10^2}$$

$$= \frac{21.01502 - 19.89160}{100} = .0112342$$

$$\text{Variance}_{1(\text{end})} = \frac{10(2.057604) - (4.424)^2}{10^2}$$

$$= \frac{20.57604 - 19.57178}{100} = .0100426$$

S Variance $=$ .0550635

Arithmetic mean $= \dfrac{\text{S Variance}}{\text{No. of columns}} =$ .0110127

Log $\text{Variance}_{1(\text{beg.})}$ $=$ 8.005223 - 10

Log Variance_{2} $=$ 8.094156 - 10

Log Variance_{3} $=$ 8.050959 - 10

Log Variance_{4} $=$ 8.050534 - 10

Log $\text{Variance}_{1(\text{end})}$ $=$ $\underline{8.001842 - 10}$

S Log Variance $=$ 40.202714 - 50

$\dfrac{\text{S Log Variance}}{\text{No. of columns}} =$ 8.040543 - 10

Geometric Mean $=$ .0109785

$L_1 = \dfrac{\text{Geometric mean}}{\text{Arithmetic mean}} = \dfrac{.0109785}{.0110127} = .99689$

	5% Level	1% Level
Significant L_1 Values (5 columns, 10 values/column)	.8025	.7350

S: summation

L_1 TEST OF ROWS OF TABLE 3

Row	SX	SX^2
A	2.657	1.418035
B	3.536	2.501650
C	2.097	0.879969
D	1.971	0.777227
E	2.387	1.143395
F	2.378	1.148626
G	2.217	0.984677
H	1.640	0.538156
I	1.918	0.739258
J	1.856	0.690538

$$\text{Variance} = \frac{N\,SX^2 - (SX)^2}{N^2} \quad \text{where } N = \text{no. of values per row}$$

$$\text{Variance}_A = \frac{5(1.418035) - (2.657)^2}{5^2} = \frac{7.090175 - 7.059647}{25}$$

$$= .00122104$$

$$\text{Variance}_B = \frac{5(2.501650) - (3.536)^2}{5^2} = \frac{12.508250 - 12.503296}{25}$$

$$= .00019816$$

$$\text{Variance}_C = \frac{5(.879969) - (2.097)^2}{5^2} = \frac{4.399845 - 4.397409}{25}$$

$$= .00009744$$

$$\text{Variance}_D = \frac{5(.777227) - (1.971)^2}{5^2} = \frac{3.886135 - 3.884841}{25}$$

$$= .00005176$$

$$\text{Variance}_E = \frac{5(1.143395) - (2.387)^2}{5^2} = \frac{5.716975 - 5.697769}{25}$$

$$= .00076824$$

$$\text{Variance}_F = \frac{5(1.148626) - 2.378)^2}{5^2} = \frac{5.743130 - 5.654884}{25}$$

$$= .00352984$$

$$\text{Variance}_G = \frac{5(.984677) - (2.217)^2}{5^2} = \frac{4.923385 - 4.915089}{25}$$

$$= .00033184$$

$$\text{Variance}_H = \frac{5(.538156) - (1.640)^2}{5^2} = \frac{2.690780 - 2.689600}{25}$$

$$= .00004720$$

$$\text{Variance}_I = \frac{5(.739258) - (1.918)^2}{5^2} = \frac{3.696290 - 3.678724}{25}$$

$$= .00070264$$

$$\text{Variance}_J = \frac{5(.690538) - (1.856)^2}{5^2} = \frac{3.452690 - 3.444736}{25}$$

$$= .00031816$$

$$\text{S Variance} = .00726632$$

$$\text{Arithmetic mean} = \frac{\text{S variance}}{\text{No. of rows}} = .000726632$$

$\text{Log Variance}_A = 7.086733 - 10$

$\text{Log Variance}_B = 6.297016 - 10$

$\text{Log Variance}_C = 5.988737 - 10$

$\text{Log Variance}_D = 5.713994 - 10$

$\text{Log Variance}_E = 6.885497 - 10$

$\text{Log Variance}_F = 7.547752 - 10$

$\text{Log Variance}_G = 6.520928 - 10$

$\text{Log Variance}_H = 5.673942 - 10$

$\text{Log Variance}_I = 6.846733 - 10$

Log Variance$_J$ = $\underline{6.502646 - 10}$

S Log Variance= 65.063978 -100

$\frac{\text{S Log Variance}}{\text{No. of Rows}}$ = 6.5063978 - 10

Geometric Mean = .00032092

$L_1 = \frac{\text{Geometric mean}}{\text{Arithmetic mean}} = \frac{.00032092}{.00072663} = .441655$

	5% Level	1% Level
Significant L_1 Values (10 rows, 5 values/row)	.6318	.5556

S: summation

L_1 TEST OF COLUMNS OF TABLE 4

Columns	SX	SX^2
First	4.669	2.281165
Second	4.571	2.210963
Third	4.517	2.163653
Fourth	4.476	2.108146
Fifth	4.424	2.057604

Variance $= \frac{NSX^2 - (SX)^2}{N^2}$ where N = No. of values per column.

$$\text{Variance}_{1st} = \frac{10(2.281165) - (4.669)^2}{10^2}$$

$$= \frac{22.81165 - 21.79956}{100} = .0101209$$

$$\text{Variance}_{2nd} = \frac{10(2.210963) - (4.571)^2}{10^2}$$

$$= \frac{22.10963 - 20.89404}{100} = .0121559$$

$$\text{Variance}_{3rd} = \frac{10(2.163653) - (4.517)^2}{10^2}$$

$$= \frac{21.63653 - 20.40329}{100} = .0123324$$

$$\text{Variance}_{4th} = \frac{10(2.108146) - (4.476)^2}{10^2}$$

$$= \frac{21.08146 - 20.03458}{100} = .0104688$$

$$\text{Variance}_{5th} = \frac{10(2.057604) - (4.424)^2}{10^2}$$

$$= \frac{20.57604 - 19.57178}{100} = .0100426$$

S Variance = .0551206

Arithmetic mean $= \frac{\text{S Variance}}{\text{No.of columns}} = .0110241$

Log Variance_{1st} = 8.005223 - 10

Log Variance_{2nd} = 8.084790 - 10

Log Variance_{3rd} = 8.091034 - 10

Log Variance_{4th} = 8.019905 - 10

Log Variance_{5hh} = 8.001842 - 10

S Log Variance = 40.202794 - 50

$\frac{\text{S Log Variance}}{\text{No. of Columns}}$ = 8.040559 - 10

Geometric Mean = .010979

$$L_1 = \frac{\text{Geometric mean}}{\text{Arithmetic mean}} = \frac{.010979}{.011024} = .99592$$

S: summation

L_1 TEST OF ROWS OF TABLE 4

(Same as for Table 3)

ANALYSIS OF VARIANCE

Total

$$SX^2 - \frac{(SX)^2}{N} = 10.821531 - \frac{(22.657)^2}{50}$$

$$= 10.821531 - \frac{513.339649}{50}$$

$$= 10.821531 - 10.266793$$

$$= .554738$$

Individuals

$$\frac{(SX)^2 \text{ of individuals A thru J}}{\frac{N}{10}} - \frac{(SX)^2}{N}$$

$$\frac{(2.657)^2 + (3.536)^2 + (2.097)^2 + (1.971)^2 + (2.387)^2 + (2.378)^2 + (2.217)^2 + (1.640)^2 + (1.918)^2 + (1.856)^2}{5}$$

$$- 10.266793$$

$$\frac{539.25997}{5} - 10.266793 = 10.785199 - 10.266793$$

$$= .518406$$

Conditions of Noise vs Music

$$\frac{(SX)^2 \text{ noise}}{20} + \frac{(SX)^2 \text{ music}}{30} - \frac{(SX)^2}{N}$$

$$\frac{(9.093)^2}{20} + \frac{(13.564)^2}{30} - 10.266793$$

$$\frac{82.682649}{20} + \frac{183.982096}{30} - 10.266793$$

$$= 4.134132 + 6.132736 - 10.266793 \doteq .000075$$

Within Noise

$$\frac{(SX_{1\ \text{end}})^2 + (SX_{1\ \text{beg.}})^2}{\frac{N_1}{2}} - \frac{(SX_1)^2}{N_1}$$

$$\frac{(4.424)^2 + (4.669)^2}{10} - \frac{(9.093)^2}{20} = \frac{41.371337}{10} - \frac{82.682649}{20}$$

$$4.137134 - 4.134132 = .003002$$

Within Music

$$\frac{(SX_2)^2 + (SX_3)^2 + (SX_4)^2}{\frac{N_2 + N_3 + N_4}{3}} - \frac{(SX_2 + SX_3 + SX_4)^2}{N_2 + N_3 + N_4}$$

$$\frac{(4.600)^2 + (4.504)^2 + (4.460)^2}{10} - \frac{(13.564)^2}{30}$$

$$\frac{61.337616}{10} - \frac{183.982096}{30} = 6.133762 - 6.132736$$

$$= .001026$$

Within Order of Presentation

$$\frac{(SX_{2nd})^2 + (SX_{3rd})^2 + (SX_{4th})^2}{\frac{N_{2nd} + N_{3rd} + N_{4th}}{3}} - \frac{(SX_{2nd} + SX_{3rd} + SX_{4th})^2}{N_{2nd} + N_{3rd} + N_{4th}}$$

$$\frac{(4.571)^2 + (4.517)^2 + (4.476)^2}{10} - \frac{(13.564)^2}{30}$$

$$\frac{61.331906}{10} - \frac{183.982096}{30} = 6.133191 - 6.132736$$

$$= .000455$$

S: summation

ANALYSIS OF VARIANCE SUMMARY

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significant F Values	
					1% Level	5% Level
Total	.554738	49	.011321			
Individuals	.518406	9	.057601	64.36	2.94	2.15
Conditions of Noise vs Music	.000075	1	.000075	0.084	6272	251
Within Noise	.003002	1	.003002	3.35	7.39	4.11
Within Music	.001026	2	.000513	0.573	99.48	19.47
Error	.032229	36	.000895			

ANALYSIS OF VARIANCE SUMMARY

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significant F Values 1% Level	Significant F Values 5% Level
Total	.554738	49	.011321			
Individuals	.518406	9	.057601	63.228	2.94	2.15
Conditions of Noise vs. Music	.000075	1	.000075	0.082	6272	251
Within Noise	.003002	1	.003002	3.295	7.39	4.11
Within Order of Presentation	.000455	2	.000228	0.250	99.48	19.47
Error	.032800	36	.000911			

APPENDIX

C

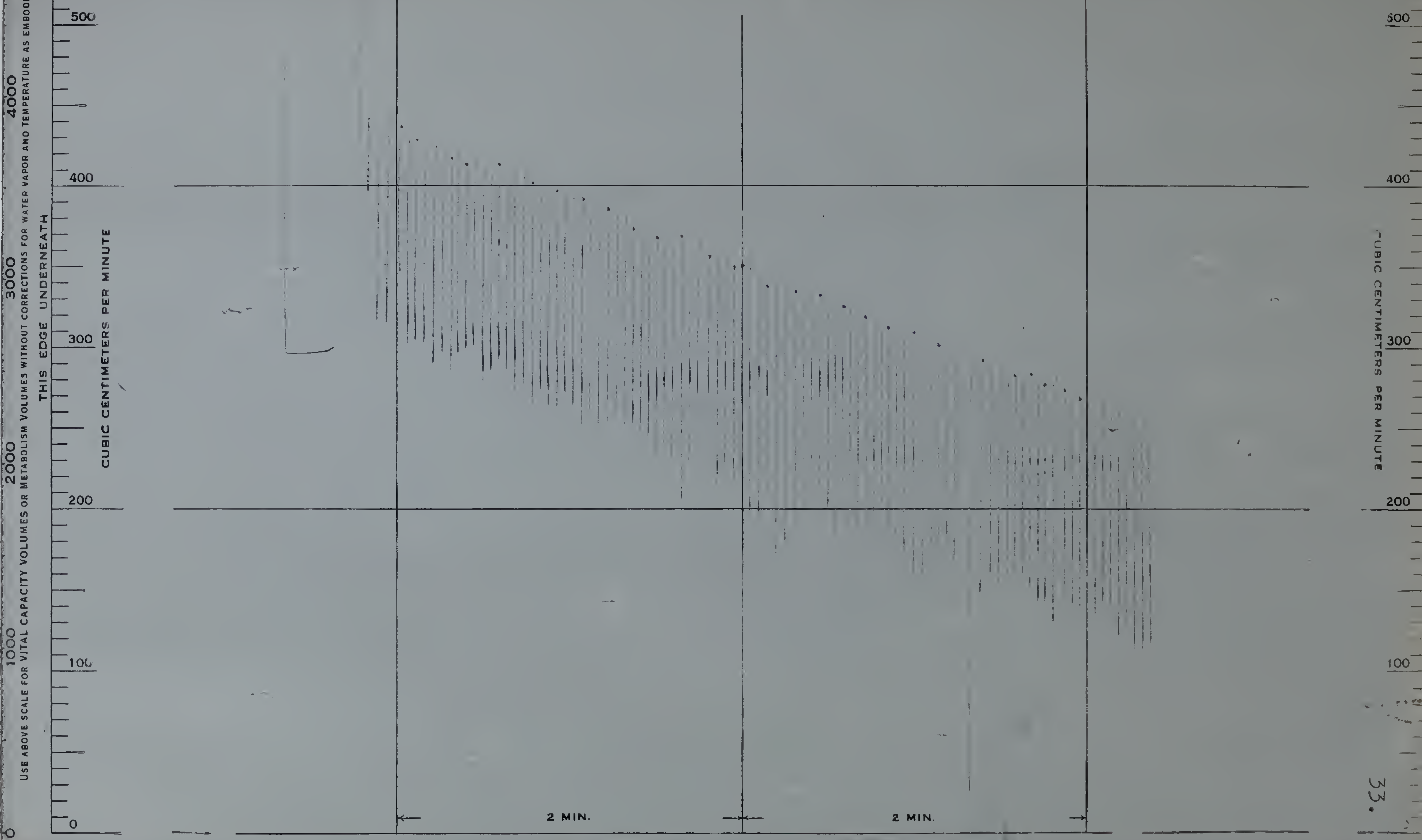
NORMAL - FROM TABLE........

AGE - SEX CORR.____

NORMAL STANDARD........
C.C. PER MIN.

BMR (TEST 1)........
(" 2)........

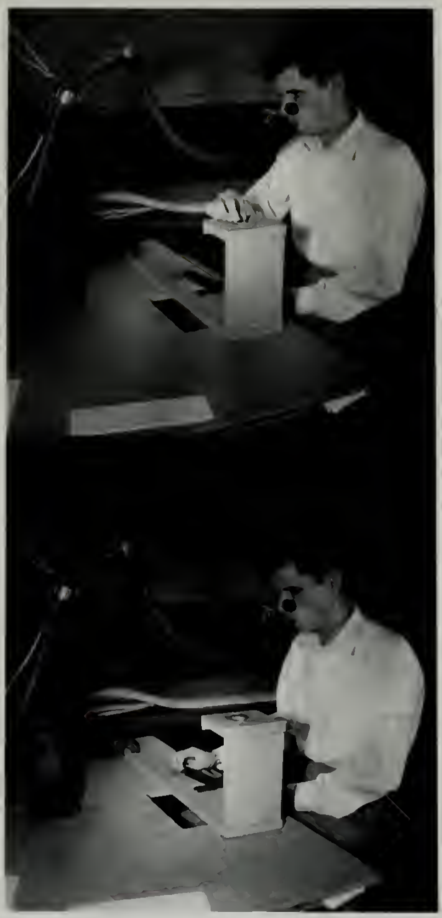
DRAW SLOPE LINE FROM LINE "A" TO EDGE "B"
READ. AT "A" (TEST 1)........ (TEST 2)........
" " "B" (" 1)____ (" 2)____
DIFFERENCE (" 1)........ (" 2)........
TEMP. CORR. (" 1)........ (" 2)........
BAR. (" 1)____ (" 2)____
ACTUAL (" 1)........ (" 2)........
C.C. PER MIN. C.C. PER MIN.



SANBORN MODEL E-I-S When Re-ordering, Specify Type 4MC PRINTED IN THE U.S.A. JUNE 1950 2.750.000

APPENDIX

D



WORKPLACE AND TASK

BIBLIOGRAPHY

Tilles, S., An Investigation Of The Suitability Of The Sanborn EIS Metabolism Tester To Basic Motion Study Experimentation, Master of Science Thesis, Purdue University, Lafayette, Indiana, 1949.

Pepinsky, A., "The Growing Appreciation of Music and Its Effect Upon the Choice of Music In Industry," Journal of the Acoustical Society of America, January, 1944, vol. 15, pp. 176-9.

Burris-Meyer, H., "Music in Industry; Results of Test," Mechanical Engineering, January, 1943, vol. 65, pp. 31-4.

Harmon, F.L., "The Effects of Noise upon Certain Psychological and Physiological Processes," Archives of Psychology, February, 1933, no. 147.

Cardinell, R.L. and Burris-Meyer, H., "Music in Industry Today," Journal of the Acoustical Society of America, July, 1947, vol. 19, no. 4, pt. 1, pp. 547-9.

Kerr, W.A., "Attitudes Towards Types of Industrial Music," Journal of the Acoustical Society of America, October, 1943, vol. 15, pp. 125-30.

Hoover, J.E., Analysis of Variation of Human Energy Consumption with Length of Movement Under Equal Pace, Master of Science Thesis, Purdue University, Lafayette, Indiana, August, 1950.

Halpin, D.D., "Industrial Music and Morale," *Journal of the Acoustical Society of America*, October, 1943, vol. 15, pp. 116-23.

Zeothout, W.D., *A Textbook of Physiology*; St. Louis, C.V. Mosby Co., 1938.

Freeman, H.A., *Industrial Statistics*; New York, J. Wiley and Sons, Inc., London, Chapman and Hall, Ltd., 1942.

Lindquist, E.F., *Statistical Analysis In Educational Research*, Boston, New York, Chicago, Atlanta, Dallas, San Francisco, Houghton Mifflin Company, 1940.

Kerr, W.A., "Experiments on the Effects of Music on Factory Production," *Applied Psychology Monographs*, January 1945, no. 5.

BIBLIOGRAPHY FOR ADDITIONAL INFORMATION

"Industrial Music - Factor in Industrial Relations," *Southern Power and Industry*, March 1947, vol. 65, no. 3, pp. 50-1, 122-3.

"Industrial Music," *Business Week*, April 3, 1943, pp. 64+

"Music Speeds Production For War; Westinghouse Lamp Division," *National Safety News*, August, 1942, vol. 46, pp. 67.

Cardinell, R.L., "Statistical Method In Determining Effects of Music In Industry," *Journal of the Acoustical Society of America*, October, 1943, vol. 15, pp. 133-5.

Tindall, G.M., "Rythm For the Restless," *Personnel Journal*, October, 1937, vol. 16, pp. 120-4.

Kerr, W.A., "Music For Workers," *Personnel Journal*, May, 1943, vol. 22, pp. 32-4.

Diserens, C.M., "Reactions to Musical Stimuli," *Psychological Bulletin*, April 1923, vol. 20, no. 4.

Schubert, H.J.P., "Energy cost Measurements on the Curve of Work," *Archives of Psychology*, May, 1932, no. 139.

"Music Does Speed Production," *Sales Management*, May 20, 1944, vol. 53, pp. 54.

Aldous, D.W., "Music As An Aid to Production," *Electrician*, May 5, 1944, vol. 132, no. 3440, pp. 388-9.

Benson, B.E., *Music and Sound Systems in Industry*, New York - London, McGraw Hill, 1945.

Housman, E., "Music While They Work," *Printers' Ink*, August 6, 1943, vol. 204, pp. 18-19.

"She Shall Have Music; Use of Recorded Music In Mill; Collins and Aikman Corp.," Textile World, December, 1941, vol. 91, pp. 105.

Andrews, E.W., "Music Goes To Work," National Safety News, May, 1943, vol. 47, pp. 13+.

AP 14 63
9 JUN 66
15 FEB 71
3 AUG 72
[illegible] 72
17 AUG 74

13515
16031
20649
21378
S10975
22618

15651

Thesis
S864
Surface
The effect of music on the metabolic rate of workers

AP 14 63
9 JUN 66
15 FEB 71
3 AUG 72
[illegible] 72
17 AUG 74

13515
16031
20649
21378
S10975
22618

Thesis 15651
S864 Surface
The effect of music on the metabolic rate of workers

Library
U. S. Naval Postgraduate School
Monterey, California

thesS864
The effect of music on the metabolic rat
3 2768 002 02213 9
DUDLEY KNOX LIBRARY